§3. Impurity Behavior for Non-Radiative Collapse

Kato, T., Suzuki, C., Funaba, H., Murakami, I., Kato, D., Goto, M., Morita, S., Peterson, B.J., Ida, K., Yamamoto, N. (Chubu Univ.)

We measure EUV spectra from fusion plasma experiments in the Large Helical Device (LHD), and study the behavior of impurities in representative cases showing radiation collapse and non-radiative collapse.

Ionization and excitation processes are dominant in plasmas while the heating is on. These processes have often been studied. However, the recombination processes have not been studied as well in experiments. In this study we are interested in recombination processes when the plasma decays. In the case of radiation collapse, the temperature derived from intensity ratios decreases towards the end of plasma. However, in the case of non-radiative collapse, the derived temperature is found to increase after the heating is terminated.[1] This suggests the radiating ions are moving to the plasma center even after the heating is terminated.

Spectra were recorded on a Schwob-Fraenkel 2 m SOXMOS spectrograph which gave an average resolving power of ~600 with a 600 mm^{-1} grating and ~ 300 with 133 mm^{-1}. Generally the line of sight of the measurement is fixed through the center of the plasma. It includes the region from the lower temperature edge to the higher temperature core.

We measured time dependent spectra every 100ms in the wavelength range of 20–46Å where the emission lines from He-like and H-like carbon ions are included. We used the intensity ratios of C V the intercombination lines (40.7Å, $1s^2$–$1s2p\ ^3P$) to the resonance line (40.3Å, $1s^2$–$1s2p\ ^1P$) in this study. We compared the observed intensity ratios and theoretical ones. Then we derived the electron temperature for C^{4+} ions. In ionizing plasma, the resonance line (40.3Å) is stronger than the intercombination lines (40.7Å), whereas the intercombination lines are stronger than the resonance line in recombining plasmas. The observed intensities of the resonance line are always stronger than those of the intercombination lines even during radiation collapse and after the heating turns off. This indicates that ionization and excitation processes are dominant even in the plasma decay phase. We derived the electron temperature assuming an ionizing plasma for the non-radiative collapse case; the derived temperatures show the lower limit values. In the case of radiation collapse, the electron temperature falls much faster than the case of non-radiative collapse. We can obtain the time evolution of the position of the C^{4+} ions by comparing the derived temperatures and the radial distributions of the electron temperature measured by Thomson scattering.

We show the time evolution of the electron temperature derived from the intensity ratios in Fig.1 for the shot #106505 which is a case of non radiative collapse. We also show the time variation of the position of C^{4+} ions. We can divide the results into three phases; i) before carbon pellet injection (3.85s), ii) after carbon pellet injection, iii) after the heating is terminated (4.8s). In phase i), the electron temperature T_e derived from the intensity ratios is rather high, 200–250 eV. In phase ii), T_e decreases to 100 eV and gradually increases to 150 eV. In phase iii), T_e is almost constant 130 eV for about 0.5 sec and then decreases to 60 eV. The position of C^{4+} ions moves towards the center rapidly after 5.2s.[2] In Fig.2 we plot the positions of C^{4+} ions from 4.85s to 5.35s by arrows on the electron radial distribution measured by Thomson scattering for each time. T_e from 5.15 to 5.25s increases from 70 eV to 150 eV, although the average electron temperature measured by Thomson scattering decreases. This indicates C^{4+} ions move towards the center. Even in the last period from 5.25 to 5.35s when T_e decreases from 150 to 60 eV, the temperature is too high to consider the C^{4+} ions are produced by recombination form C^{5+}. Therefore we consider C^{4+} ions are moving towards the center by themselves. The moving velocity is about 300 cm/s during 5.25–5.35s.

We made a simulation calculation by STRAHL[3] including time variation of electron temperature and density distributions with the diffusion coefficient 0.1 m^2/s. Qualitatively we obtained the similar behaviour of C^{4+} ions to our measurement.

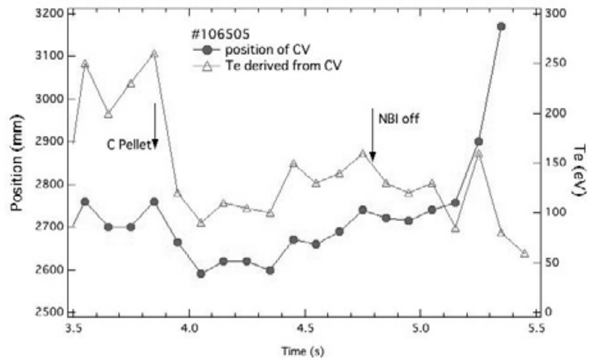

Fig. 1. The time evolution of the electron temperature derived from the intensity ratios and the position of C^{4+}.

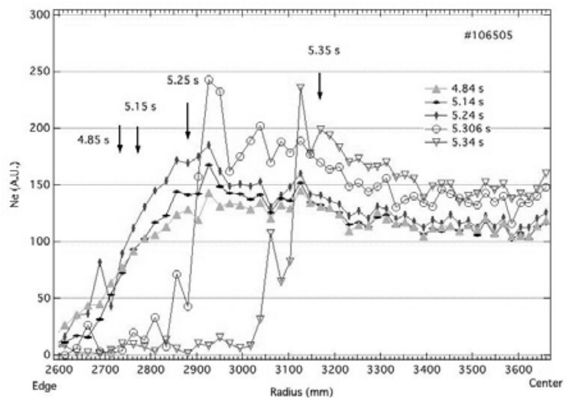

Fig. 2. The position of the C^{4+} ions shown by arrows on the electron density distributions for each time.

1) Kato, T. et al: J. Phys. Conf. Series, **163** (1985) 012101.
2) Kato, T. et al: NIFS-PROC-81 (2010) 1.
3) Dux R.: STRAHL, Manual Report, IPP 10/30 (2006).